Key feature of the presented switching method: in normal operating conditions each TF is switched immediately. In particular conditions, e.g., protection, (some) TFs are delayed.

The frequency of the selected time reference is recovered and this is enough to work properly without slips. The phase can be recovered if the link length is known.

From the foregoing, it will be observed that numerous variations and modifications may be effected without departing from the spirit and scope of the invention. It is to be understood that no limitation with respect to the specific apparatus illustrated herein is intended or should be inferred. It is, of course, intended to cover by the appended claims all such modifications as fall within the scope of the claims.

WHAT IS CLAIMED IS:

1. A switching system having a plurality of communications switches each having a plurality of inputs and a plurality of outputs for switching data units in time frames, the system further comprising of:

a first communications switch and a second communications switch connected by at least one communications channel for transmitting a plurality of data units in time frames through said communications channel to the output of the switching system;

wherein each of the inputs of each of the communications switches is coupled to a plurality of uniquely addressable incoming communications channels and each of the outputs of each of the communications switches is coupled to a plurality of uniquely addressable outgoing communications channels;

a common time reference (CTR);

wherein the CTR is divided into a plurality of contiguous periodic super cycles (SCs) each comprised of at least one contiguous time cycle (TC) each comprised of at least one contiguous time frame (TF);

wherein the CTR is coupled to each of the communications switches;

wherein the TF has associated therewith at least one of header control information and trailer control information;

wherein the data units associated with the time frames (TFs) are received over the incoming communications channels and transmitted over the outgoing communications channels; and

wherein the data units associated with selected ones of the TFs are forwarded over selected ones of the outgoing communications channels of the first communications switch and then forwarded over selected ones of the outgoing communications channels of the second communications switch responsive to at least one of the CTR, the header control information, and the trailer control information.

2. The system as in claim 1,

wherein there is a predefined delay between when data units associated with each selected one of the TFs are forwarded from the first communications switch and the second communications switch.

3. The system as in claim 1,

wherein the selected ones of the outgoing communications channels of the second communications switch are determined by the header control information and the forwarding time for the data units is determined by the CTR and the header control information.

4. The system as in claim 1,

wherein there are a plurality of second communications switches each coupled via a separate communications channel to the first communications switch.

5. The system as in claim 4,

wherein selected ones of the data units for the associated TFs are forwarded to selected ones of the plurality of second communications switches.

6. The system as in claim 2,

wherein the predefined delay is at least one of: an integer number of TFs, an integer number of TFs and a fraction of a TF, a fraction of a time cycle, a fraction of a super cycle.

7. The system as in claim 1,

wherein there is no header control information.

8. The system as in claim 1,

wherein there is no trailer control information.

9. The system as in claim 1,

wherein at least one of the header control information and the trailer control information includes a field for checking for the correct transmission of the data units that are contained within the respective time frame.

10. The system as in claim 1, further comprising:

a plurality of mapping and alignment subsystems;

wherein the incoming communications channels are coupled to the mapping and alignment subsystems;

a switch fabric;

a switch controller;

wherein the mapping and alignment subsystems are coupled to the switch fabric;

wherein the switch fabric is coupled to the outgoing communications channels;

wherein the CTR is coupled to the switch controller; and

wherein the switch controller is coupled to the mapping and alignment subsystems and the switch fabric.

11. The system as in claim 10,

wherein each of the mapping and alignment subsystems is further comprised of: a plurality of time frame queues (TF-queues) and a mapping controller; and

wherein the mapping controller stores the data units received in each of the time frames of a respective one of the incoming communications channels in one of the TF-queues responsive to at least one of the header control information, the trailer control information and the CTR.

12. The system as in claim 11,

wherein the header control information further contains a routing label; and

wherein the routing label is used for selecting the respective TF-queue within which the data units received in the respective time frame should be stored.

13. The system as in claim 12,

wherein the switch controller couples, in every time frame through the switch fabric, a selected one of the TF-queues to at least one of the outgoing communications channels for output forwarding of the data units received in said TF-queue during respective ones of the time frames.

14. The system as in claim 13,

wherein the routing label in the header control information is replaced by a new header control information prior to the output forwarding.

15. The system as in claim 12,

wherein the routing label is at least one of: ATM virtual circuit (VC) label, ATM virtual path (VP) label, MPLS label, IP v4 address, IP v6 address, fiber channel address and, Ethernet MAC address.

16. A switching system having a plurality of communications switches each with a plurality of inputs and a plurality of outputs for switching data units in time frames, the system further comprising:

a first communications switch, a second communications switch and a third communications switch;

wherein the first communications switch is connected by at least one first communications channel to the second communications switch for transmitting a plurality of data units in time frames through the first communications channel to the output of the switching system;

wherein the first communications switch is connected by at least one second communications channel to the third communications switch for transmitting a plurality

of data units in time frames through the second communications channel to the output of the switching system;

wherein each of the inputs of each of the communications switches are coupled to a plurality of uniquely addressable incoming communications channels and each of the outputs of the communications switches is coupled to a plurality of uniquely addressable outgoing communications channels;

a common time reference (CTR);

wherein the CTR is divided into a plurality of contiguous periodic super cycles (SCs) each comprised of at least one contiguous time cycle (TC) each comprised of at least one contiguous time frame (TF);

wherein the CTR is coupled to each of the communications switches;

wherein selected one of the TFs have at least one of header control information and trailer control information;

wherein the data units for consecutive TFs are received over the incoming communications channels and transmitted over outgoing communications channels; and

wherein the data units for selected ones of the TFs are forwarded over selected ones of the outgoing communications channels of the first communications switch and then forwarded over selected ones of the outgoing communications channels of the second communications switch responsive to the CTR and the header control information.

17. The system as in claim 16, further comprising:

means for detecting failure in transmitting of the plurality of data units in time frames through the first communications channel to the second communications switch; and

wherein responsive to detecting failure through the first communications channel to the second communications switch, said respective data units in time frames are forwarded through the second communications channel to the third communications switch.

18. The system as in claim 17, further comprising:

means responsive to detecting failure of communications of the data units through the first communications channel to the second communications switch, to provide that said respective data units in time frames are forwarded through the second communications channel to the third communications switch.

19. The system as in claim 11,

wherein the header control information further contains a routing label.

20. The system as in claim 19,

wherein the routing label in the header control information is replaced by a new routing label prior to the data units in selected ones of the TFs are forwarded over selected ones of the outgoing communications channels.

21. The system as in claim 19,

wherein the routing label is at least one of: ATM virtual circuit (VC) label, ATM virtual path (VP) label, MPLS label, IP v4 address, IP v6 address, fiber channel address and, Ethernet MAC address.

22. A switching system, comprising:

a switch apparatus for switching data units contained within defined ones of a plurality of contiguous time frames, between a plurality of input ports and a plurality of output ports, wherein each of the time frames has associated control information;

a Common Time Reference (CTR) divided into time frames (TFs);

a plurality of mapping and alignment subsystems (MAS), each said MAS coupled to a respective one of the input ports, and responsive to the CTR and the associated control information for providing an aligned output that is aligned to the CTR and that contains the respective data units from the respective input port for each of the respective time frames;

a switch fabric providing for coupling of the data units from the aligned outputs for each of the time frames to respective ones of the output ports responsive to the CTR and the associated control information; and

wherein the data units at the input ports contained within a single time frame are provided to the output ports within a single time frame.

23. The system as in claim 22, wherein the data units at the input ports contained within a single time frame are provided as aligned outputs within a single time frame.

24. The system as in claim 22, wherein the MAS is further comprised of:

a plurality of time frame queues; and

a mapping subsystem comprising: a mapping controller coupled to receive the data units within the time frames from the respective input port, and a time frame mapping table, for defining associative mapping of the received data units received within the respective time frame to a respective one of the time frame queues, responsive

to the CTR and the respective control information associated with the respective time frame.

25. The system as in claim 24, further comprising:

means for storing the respective data units in respective ones of the time frame queues responsive to the mapping subsystem.

26. The system as in claim 25, further comprising:

a forwarding controller comprising a time frame queue mapping table for defining associative mapping between the time frame queue outputs and the respective time frames during which to forward the time frame queue output as the respective aligned output; and

a scheduling subsystem for selectively forwarding the data units from the time frame queues to provide the respective alignment output, responsive to the CTR and to the time frame queue mapping table.

27. The system as in claim 26,

wherein the associated control information further contains a routing label; and

wherein the routing label is used for selecting the respective time frame queue within which the data units received in the respective time frame should be stored.

28. The system as in claim 27,

wherein the switch apparatus couples, in every time frame through the switch fabric, a selected one of the time frame queues to at least one of the output ports for

output forwarding of the data units received in said time frame queue during respective ones of the time frames.

29. The system as in claim 28,

wherein the routing label in the associated control information is replaced by a new control information prior to the data units in selected ones of the TFs are forwarded from selected ones of the outputs.

30. The system as in claim 27,

wherein the routing label is at least one of: ATM virtual circuit (VC) label, ATM virtual path (VP) label, MPLS label, IP v4 address, IP v6 address, fiber channel address and, Ethernet MAC address.

31. The system as in claim 26,

wherein the associated control information further contains a time frame delimiter; and

wherein the time frame delimiter is used for identifying the respective time frame beginning and end.

32. A method of switching data units contained within time frames, between a plurality of input ports and a plurality of output ports, the method comprising:

providing a Common Time Reference (CTR); dividing the CTR into defined ones of a plurality of contiguous time frames;

associating control information with each of the time frames;

providing for each of the input ports, an aligned output that is aligned to the CTR and that contains the respective data unit from the respective input port for each of the respective time frames responsive to the CTR and the associated control information;

providing for coupling of the data units from the aligned outputs for each of the time frames to respective ones of the output ports responsive to the CTR; and

providing the data units to the output ports within a single time frame for respective ones of the data units at the input ports having the data units contained within a signal time frame.

33. The method as in claim 32, further comprising:

providing as aligned outputs within a single time frame the data units at the input ports contained within a single time frame.

34. The method as in claim 32, further comprising:

providing a plurality of time frame queues;

receiving the data units within time frames from the respective input port;

defining associative mapping of the received data units received within the respective time frame to a respective one of the time frame queues, responsive to the CTR and the respective control information associated with the respective time frame.

35. The method as in claim 34, further comprising:

storing the respective data units in respective ones of the time frame queues responsive to the associative mapping.

36. The method as in claim 35, further comprising:

defining the associative mapping of time frame queues between the time frame queue outputs and the respective time frame during which to forward the time frame queue output as the respective aligned output; and

selectively forwarding the data units from the time frame queues to provide the respective alignment output, responsive to the CTR and to the associative mapping of the time frame queues.

37. The method as in claim 32, further comprising:

providing a routing label within the control information;

selecting the respective time frame queue within which the data units received in the respective time frame should be stored, responsive to the routing label.

38. The method as in claim 37, further compromising:

coupling in every time frame a selected one of the time frame queues to at least one of the output ports for output forwarding of the data units received in said time frame queue during respective ones of the time frames.

39. The method as in claim 38 further comprising:

replacing the routing label in the control information by a new header control information prior to the output forwarding.

40. The method as in claim 37,

wherein the routing label is at least one of: ATM virtual circuit (VC) label, ATM virtual path (VP) label, MPLS label, IP v4 address, IP v6 address, fiber channel address and, Ethernet MAC address.

41. A switching system having a plurality of communications switches each with a plurality of inputs and a plurality of outputs for switching data units in time frames, the system further comprising:

a first communications switch, a second communications switch and a third communications switch;

wherein the second communications switch is connected by at least one communications channel to the first communications switch for transmitting a plurality of data units in time frames through said communications channel to the output of the switching system;

wherein the third communications switch is connected by at least one communications channel to the first communications switch for transmitting a plurality of data units in time frames through said communications channel to the output of the switching system;

wherein each of the inputs of each of the communications switches are coupled to a plurality of uniquely addressable incoming communications channels and each of the outputs of the communications switches is coupled to a plurality of uniquely addressable outgoing communications channels;

a common time reference (CTR);

wherein the CTR is divided into a plurality of contiguous periodic super cycles (SCs) each comprised of at least one contiguous time cycle (TC) each comprised of at least one contiguous time frame (TF);

wherein the CTR is coupled to each of the communications switches;

wherein the TF has at least one of header control information and trailer control information;

wherein the data units for consecutive TFs are received over the incoming communications channels and transmitted over outgoing communications channels; and

wherein the data units for selected ones of the TFs are forwarded over selected ones of the outgoing communications channels of the second communications switch and then forwarded over selected ones of the outgoing communications channels of the first communications switch responsive to the CTR and the header control information.

42. The system as in claim 41, further comprising:

means for detecting failure in transmitting of the plurality of data units in time frames through said communications channel from the second communications switch; and

wherein responsive to detecting failure through said communications channel to the first communications switch, said respective data units in time frames are forwarded through said communications channel from the third communications switch.

43. The system as in claim 42, further comprising:

means responsive to detecting failure of communications of the data unit from said second communications switch, to provide that said respective data units in time frames are forwarded through said communications channel from the third communications switch.

44. A communication system, comprising:

a Common Time Reference (CTR) signal comprising a plurality of contiguous time frames;

a plurality of switching subsystems, each comprised of a plurality of input ports and output ports for switching of data units associated with defined ones of the time frames having associated control information, wherein each of the switching subsystems forms a node in a fractional lambda pipe, wherein a first plurality of the nodes forms a primary fractional lambda pipe comprised of a chain of connected ones of the nodes each beginning with a pipe switch node and ending with a pipe merge node, wherein a second plurality of the nodes forms a protection fractional lambda pipe comprised of a second chain of connected ones of the nodes beginning with the pipe switch node and ending with the pipe merge node;

a scheduling output providing assignment of a sequence of time frames to each of the primary fractional lambda pipe and the protection primary lambda pipe; and

wherein all the data units associated with a respective one of time frames are routed via one of the primary fractional lambda pipe and the protection fractional lambda pipe, responsive to the CTR and the scheduling output.

45. The system as in claim 44, further comprising:

first means for coupling the data units via the primary fractional lambda pipe;

means for detecting improper operation of the primary fractional lambda pipe; and

second means for coupling the data units via the protection fractional lambda pipe responsive to the detecting means.

46. The system as in claim 45, wherein the first means is responsive to the CTR, and wherein the second means is responsive to the CTR.

47. The system as in claim 46, wherein at least one of the first means and the second means for coupling is further responsive to the associated control information.

48. The system as in claim 45, wherein the first means for coupling and the second means for coupling are further comprised of the pipe switch node and the pipe merge node.

49. The system as in claim 45, wherein the pipe switch node determines the selection of one of the primary fractional lambda pipe and the protection fractional lambda pipe, responsive to the CTR, the control information, and the means for detecting.

50. The communications system as in claim 45,

wherein the switching subsystem is comprised of a switch fabric having an associated switch fabric configuration that defines a coupling arrangement for the input ports to the output ports for each time frame; and

wherein the first means for coupling and the second means for coupling are each comprised of a separate switch fabric configuration.

51. The system as in claim 45, wherein each of the first means for coupling and the second means for coupling are comprised of means for mapping the data units to the associated time frame.

52. The system as in claim 44, wherein the data units are provided from at least a first source and a second source;

wherein the protection fractional lambda pipe provides for coupling and routing of the data units of the second source, and wherein the primary fractional lambda pipe provides for coupling the data units from the first source.

53. The system as in claim 52, wherein responsive to an interruption in the coupling of the data units among the nodes of the primary fractional lambda switch, the respective data units are re-routed for coupling among the nodes of the protection fractional lambda pipe, responsive to the CTR and the respective control information.

54. The system as in claim 44,

wherein the data units are provided from at least a first source and a second source; and

wherein the primary fractional lambda pipe is further comprised of at least a first and a second primary fractional lambda pipes, each comprised of a plurality of interconnected nodes, wherein the data units form the first source are routed to the first primary fractional lambda pipes if available, and the data units form the second source are routed to the second primary fractional lambda pipe if available, wherein when one of the first and second primary fractional lambda pipes is unavailable, then the respective data units are coupled via the protection fractional lambda pipe.

55. A switching method, for use with a switching system having inputs and outputs and comprised of a plurality of communications switches each having a plurality of inputs and a plurality of outputs for switching data units in time frames, the method comprising:

connecting a first communications switch and a second communications switch by at least one communications channel;

transmitting a plurality of data units in time frames through said communications channel to the output of the switching system;

coupling each of the inputs of each of the communications switches to a plurality of uniquely addressable incoming communications channels;

coupling each of the outputs of each of the communications switches to a plurality of uniquely addressable outgoing communications channels;

providing a common time reference (CTR);

dividing the CTR into a plurality of contiguous periodic super cycles (SCs) each comprised of at least one contiguous time cycle (TC) each comprised of at least one contiguous time frame (TF);

coupling the CTR to each of the communications switches;

associating each of the TF with at least one of header control information and trailer control information;

receiving the data units associated with the time frames (TFs) over the incoming communications channels;

transmitting the data units associated with the time frames (TFs) over outgoing communications channels;

forwarding the data units associated with selected ones of the TFs over selected ones of the outgoing communications channels of the first communications switch and then forwarding the data units associated with selected ones of the TFs over selected ones of the outgoing communications channels of the second communications switch responsive to at least one of the CTR, the header control information, and the trailer control information.

56. The method as in claim 55, further comprising:

providing a predefined time delay between when selected ones of the data units associated with each selected one of the TFs are forwarded from the first communications switch and when the selected ones of the data units are forwarded out from the second communications switch.

57. The method as in claim 55, further comprising:

determining the selected one of the outgoing communications channels of the second communications switch responsive to the header control information; and

determining the forwarding time for the data units responsive to the CTR and the header control information.

58. The method as in claim 55, further comprising:

coupling a plurality of second communications switches via a separate communications channel to the first communications switch.

59. The method as in claim 58, further comprising:

forwarding selected ones of the data units for the associated TFs to selected ones of the plurality of the second communications switches.

60. The method as in claim 56,

wherein the predefined delay is at least one of: an integer number of TFs, an integer number of TFs and a fraction of a TF, a fraction of a time cycle, a fraction of a super cycle.